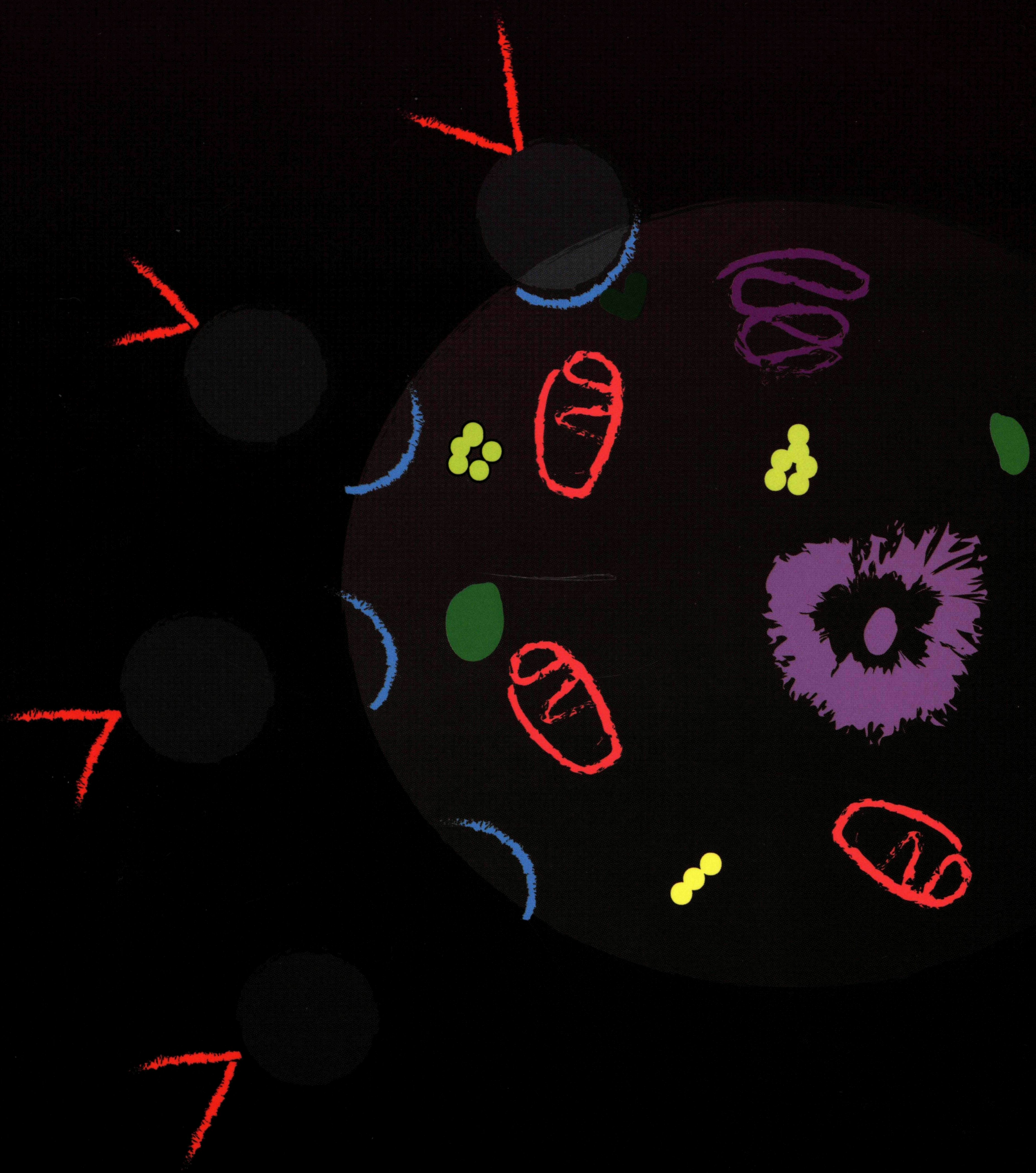
Volume 1 | 2015

COMPENDIUM OF ORAL SCIENCE

The Official Journal of The Faculty of Dentistry



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COMPENDIUM OF

ORAL SCIENCE

The Official Journal of The Faculty of Dentistry

Volume 1|2015
ISSN: 2489-1102

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Contents

Original Article

Detail Reproduction of Elastomeric Materials: Effect of Viscosity and Groove Geometry

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Abstract

Objective: To evaluate the effect of type of viscosity and groove on surface detail reproduction of elastomeric impression materials. **Methods:** Two polyvinylsiloxane and polyether elastomeric impression materials were investigated. An aluminium cylindrical reference block with V- and U-shaped grooves of 1 mm and 2 mm in depth was machined using CAD-CAM system. Impressions of the block were taken to produce 35 master dies. Each die was immersed in distilled water for 5 minutes prior to impression making. Surface topography of the dies and impressions were captured using Alicona Imaging System. Mean difference in depth between the master dies and corresponding impressions' grooves were analyzed. **Results**: Type of viscosities and groove showed significant main effects on surface detail ($p < .01$), but no significant interaction was observed between the two ($p > .01$). Express™ putty/light exhibited the lowest mean difference in depth for all grooves. The highest mean difference for U_1 (38.3µm ± 21.55), U_2 (52.96µm ± 30.39),V_1 (45.02µm ± 34.82) and V_2 (58.44µm ± 44.19) was obtained from Impregum medium, Aquasil medium, Impregum™ heavy/light and Impregum™ heavy/light groups respectively. **Conclusion:** Express putty/light-bodied material produced the best surface detail, and U-shaped groove showed superior detail reproduction.

Key words: elastomeric materials, surface detail, effect of viscosity, groove geometry, mean difference in depth.

Introduction

Elastomeric impression materials are used to record the margin of prepared tooth and the surrounding soft tissue for the fabrication of definitive restorations. Currently, polyether (PE) and polyvinylsiloxane (PVS) are the most widely used elastomeric impression materials due to their superior properties which include dimensional accuracy and stability (1,2), excellent elastic recovery, ease of handling, ability to produce multiple casts and good detail reproducibility (3,4). During impression making, the materials are in contact with moisture such as saliva, gingival exudate and blood around the gingiva (2). The widespread use of PE and PVS is also attributed to their hydrophilic property and ability to flow into small areas and crevices (5).

The hydrophilicity of elastomeric impression

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materials is a desirable property in ensuring accurate casts (6). Polyether has been shown to be one of the most hydrophilic impression material (1,3,7,8) owing to the functional groups that chemically attract and interact with water molecules via hydrogen bonding (9,10). Whilst polyvinylsiloxane has been rendered hydrophilic by the addition of nonionic surfactants (11,12). The increased in wettability results from the surfactants acting through a diffusion transfer of surfactant molecules from the polyvinylsiloxane into the aqueous phase (5).

The literature revealed that various methods has been employed to determine the hydrophilicity of elastomeric impression materials. Contact angle measurement is the most popular (6,8,10,13) and some had used the Drop Shape Analysis System (14,15). Most of the studies showed that polyether is most hydrophilic followed by polyvinylsiloxane (14,16,17,18) but has not been demonstrated in a simulated clinical condition. The ability of elastomeric impression materials to reproduce surface details accurately on moist surface is directly linked to the hydrophilic behaviour of these materials and the accuracy of surface detail reproduction can be assessed using the standard method for elastomer as described by ISO 4823: 2000 where three engraved lines; 20, 50 and 75 μm in width on a stainless steel reference block must be reproduced in full length between two perpendicular reference lines when inspected under a stereomicroscope at 12x magnification. However, this testing model is primarily a method to assess the consistent quality of the impression material and does not simulate clinical conditions where moisture on dental substrate and surrounding soft tissues is a major concern. Petrie et al (8) and McCabe & Carrick (10) had attempted to simulate moist surface during impression making by utilising fine mist of water on stainless steel surface and moist gypsum casts respectively.

Although the literature had addressed the issues of hydrophilicity and surface reproduction of elastomeric impression materials on moist surfaces, there is lack of information on the effect of different finishing margins of tooth preparation either supra- or subgingivally placed. McCabe & Carrick., 2006 (10) investigated the effect of depth of V-shaped grooves between 5 μm to 180 μm. They reported that polyether exhibited the best surface detail reproduction when impression were made on moist gypsum casts (10,18,19). Finger et al (20) investigated the depth reproduction of different sulcus width (50,100 and 200) μm. They found that polyether material reproduced narrow sulcus better than other impression materials.

Finishing margins for extracoronal restorations can either be knife-edged, chamfer, bevel, shoulder or shoulder with bevel. Geometrically the V-shaped groove can represent the knife-edge, chamfer and beveled type finishing margins. However, a U-shaped groove is probably more appropriate to represent the shoulder or shoulder with bevel typed finishing margins (Figure 1).

Furthermore, there is no information in the literature correlating both shapes and depth of tooth preparation margins surface detail reproduction of elastomeric impression materials.

Therefore, the objective of this study is to investigate the effect of shape and depth of grooves on moist stone cast on the surface detail reproduction of elastomeric impression materials.

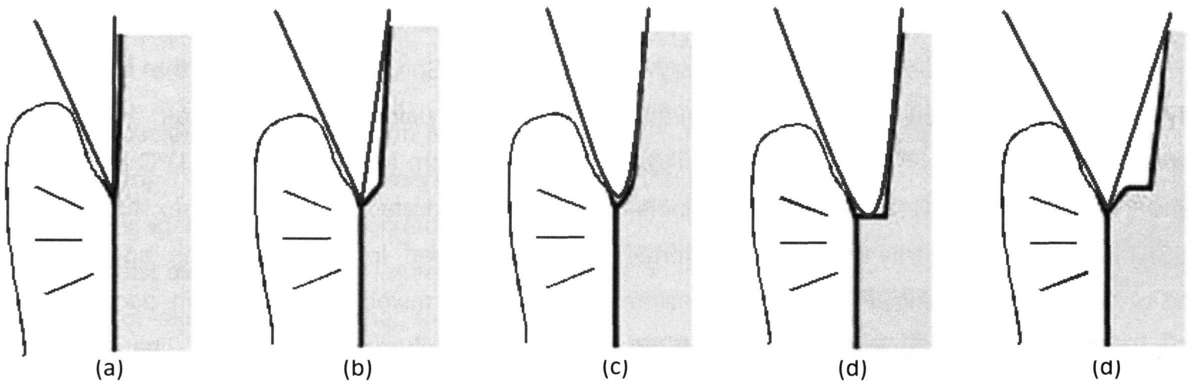

Figure 1: Various types of tooth preparation margins
(a) Knife-edge (c) Chamfer (e) Beveled shoulder
(b) Bevel (d) Shoulder

Materials and Method

The materials included in the study are shown in Table 1 and were used according to their manufacturer's instructions.

Preparation of reference block and master dies

An aluminium master block, 21 mm thick and measuring 40 mm in diameter, incorporating V and U-shaped grooves of 1mm (U_1 and V_1) and 2mm (V_2 and U_2) in depth was machined using CAD-CAM system (Micromachine DT110, Microtools PTE LTD, Singapore) incorporating three reference points of 2.5 mm apart (L1, L2, and L3) and a shoulder of 3 mm in height and width was also added to aid in the measurement and impression making respectively (Figure 2).

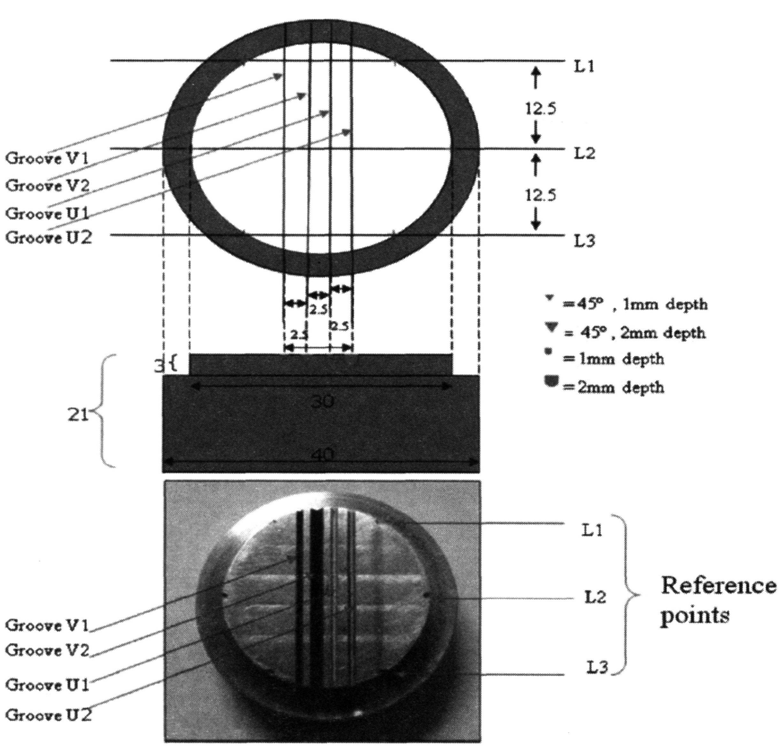

Figure 2: Calibrated grooves on aluminum block

Five impressions were made from the aluminum master block using automixed polyvinylsiloxane impression material, light- and heavy-bodied (Examix™ NDS Injection Type and Heavy Body, GC America Inc., Illinois, USA) in a customised tray made from perforated circular perpex tubing. For each impression the light-bodied material was syringed into the grooves from one end to the other using an intraoral tip. The material was pushed ahead of the syringe tip to ensure no entrapment of air until all the grooves and shoulder areas were covered. The heavy bodied material was then loaded into the tray. A polythene sheet was placed on top of the tray and dead weights of 1,500 g (ISO 4823:2000) were placed for 5 seconds and impression material was allowed to set for 5 minutes.

Prior to casting in Type IV die stone ((Velmix, Kerr Italy Spa, Scafati, Italy), the impression was dried using compressed air and left to stand at room temperature (23±1)°C for 1 hour. A non-perforated circular perspex tubing was then attached to the impression and the die stone was mixed under vacuum according to the manufacturer's instructions. The die stone was then allowed to set for 1 hour at room temperature. Each of the 5 impressions was poured 7 times until 35 die stones were obtained. These die stones were randomly divided into 5 groups (A, B,C, D and E) and later act as the master dies for making the impression using all the test materials described in Table 1.

Brand name	Batch number	Manufacturer	Type	Group
Polyvinylsiloxane				
Aquasil Ultra LV Smart Wetting® Regular Set	060306	Denstply Caulk,,Milford, DE 19963 USA	light - bodied	A
Aquasil Soft Putty- Regular Set	0711000878	Denstply De Trey GmbH, Konstanz, Germany	putty	
Aquasil Ultra Monophase Smart Wetting® Regular Set	070926	Denstply Caulk,,Milford, DE 19963, USA	medium - bodied	B
Express™ XT Light Body	B 296442	3M ESPE AG,D-82229 Seefeld, Germany	light - bodied	C
Express™ XT Putty Soft	ZP 0010476		putty	
Polyether				
Impregum™ Penta™	316658	3M ESPE AG,D-82229 Seefeld, Germany	medium - bodied	D (control)
Impregum™ Garant™ L Duosoft™	B 273781		light- bodied	E
Impregum Penta H Duosoft	316658		heavy- bodied	

Table 1. Impression materials used in this study

Impression making and evaluation of surface detail reproduction

Each master die was left at room temperature (23±1)°C for 7 days before immersing in distilled water at (37±1)°C for 5 minutes to produce a moist die stone for the impression making. A pilot study revealed that the optimum duration for Velmix die stone of 40 mm in diameter and 21 mm thick to be fully saturated with water is 5 minutes. Impression making procedures for all tested materials were as described in the master die preparation stage. All medium - and light-bodied impression materials were syringed using auto-mixing impression dispenser except for Impregum Penta and Impregum Penta H Duosoft which was dispensed using a mechanical dispenser (Pentamix 2, 3M ESPE, St Paul,USA).

The topography of all the master dies and its impressions were recorded using a high resolution 3D optical scanner (InfiniteFocus, Alicona Imaging GmbH, Austria). A master die was placed on motorized stage with magnification and vertical resolution selected at 5x and 60μm respectively. The coaxial white light was delivered through a ring light. The start and end positions on the master die was determined by moving the cursor at a horizontal plane between the two reference points. A preliminary scan (Figure 2) which was carried out to determine the highest and lowest points at each reference point; L1, L2 and L3. The entire 3D image which constitute the depths of grooves were then stitched and measurements were then obtained using the software, Alicona Version 2.1.5 Generation 4, 2008. The same procedure was repeated for the impression. Both master die and impression were illustrated in 3D true colour and pseudocolour (Figure 3).

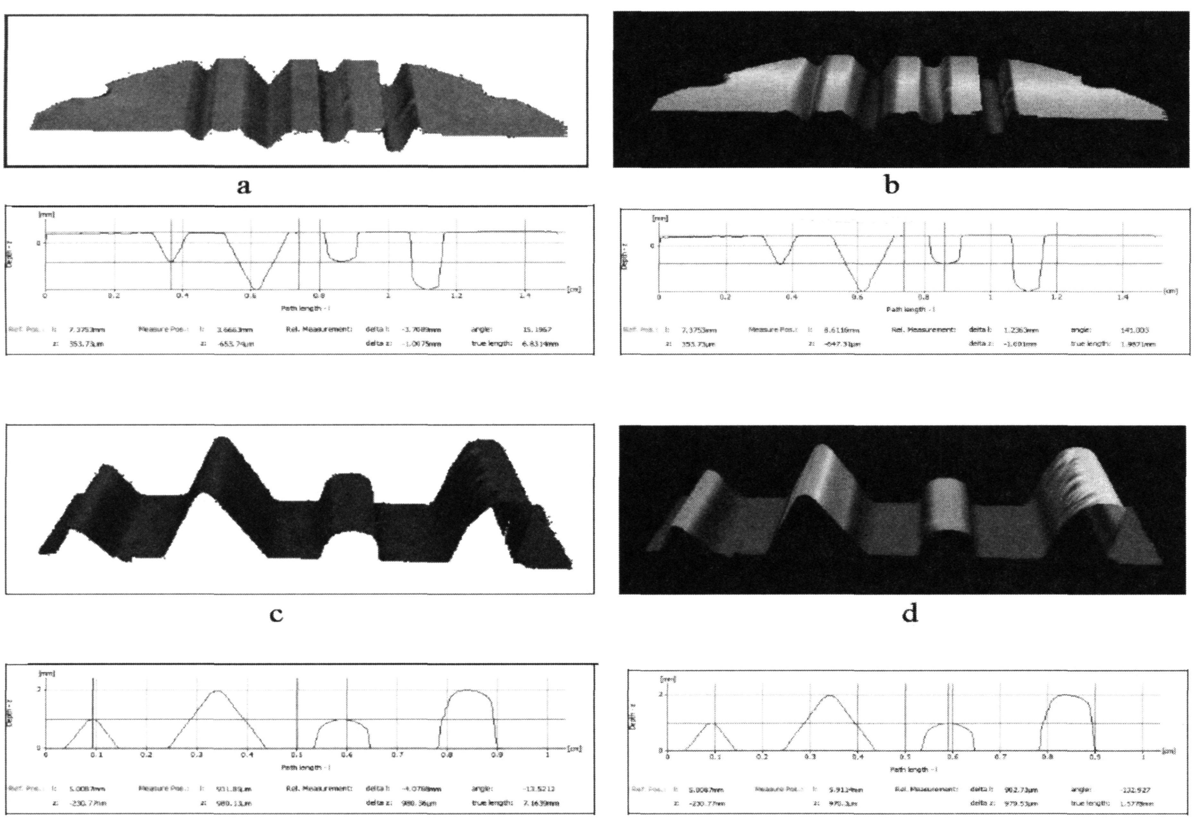

Figure 3: Illustration of 3D image of master die with true colour and pseudocolour images (a,b) and 2D measurement of master die's grooves (V_1,V_2,U_1 and U_2)

Illustration of 3D image Express™ XT Light Body and Putty Soft with true colour and pseudocolour images (c,d) and 2D measurement of Express™ XT Light Body and Putty Soft Grooves (V_1,V_2,U_1 and U_2)

The multicolour indicator in pseudocolour image mode illustrates depth of each grooves clearly. The reference plane was determined on the image before recording the depth of the grooves in z-direction as described by McCabe & Carrick 2006 (10). Depth measurements for each groove were taken at each of the three reference lines for both master dies and their correponding impressions. Measurements were also taken at 1mm above and 1mm below each reference line. The total number of depth measurements for 7 master dies and their corresponding impression was 9, giving a total of 63 measurements for each impression material tested. The mean difference in depth between the master die and its corresponding impression was computed for analysis. Profiles of all impressions were inverted so that impression of grooves could be readily compared with master die.

Results

The mean difference in depth between the masters dies and its impressions for all grooves type were analyzed using a statistical package (SPSS v12, SPSS IBM Corp., Chicago, USA). Two-way ANOVA with post hoc multiple comparisons tests and One-way ANOVA were employed, with the confidence level set at $p = 0.01$ for statistical significance.

The mean difference in depth of grooves for each material is displayed in Table 2. Two-way ANOVA revealed no interaction between type of impression materials and grooves ($p > .01$). However, there was significant difference for impression materials and grooves. The Dunnett t (2-sided) post hoc test showed that Aquasil putty/light and Express putty/light exhibited significantly lower mean difference in depth compared to Impregum medium (control group). For multiple comparisons between test groups (Games Howell test), significant difference were observed for Express putty/light which recorded the lowest mean difference in depth (17.86µm ± 17.84) in the reproduction of U-shaped groove of 1mm and Impregum heavy/light recorded the highest mean difference in depth (58.44µm ± 44.19) in the reproduction of V-shaped groove of 2mm ($p < 0.01$).

One-way ANOVA revealed that there was no significant difference between all materials in the V-shaped groove of 2 mm depth. In the re-

Materials /Groups (n=63)	Groove Geometry			
	V-Shaped		U-Shaped	
	1mm (depth) Mean (SD)	2mm (depth) Mean (SD)	1mm (depth) Mean (SD)	2mm (depth) Mean (SD)
Aquasil putty/light	30.09±27.83	46.67±26.60	27.35±16.00	37.17±28.33
Aquasil medium	30.26±28.28	52.09±39.22	27.04±21.17	52.96±30.40
Impregum medium (control)	43.26±28.53	51.85±32.63	38.31±21.55	41.18±24.10
Impregum heavy/light	45.03±34.82	58.44±44.19	34.59±31.00	41.66±31.53
Express putty/light	25.07±23.65	40.40±30.22	17.86±17.83	28.38±28.34

Table 2. The mean difference in depth for each material and groove is displayed in the table

production of U- and V-shaped grooves of 1 mm in depth, significant differences were only detected between Impregum heavy/light, Impregum medium and Express putty/light. Significant difference was detected between Aquasil putty/light, Aquasil medium and Express putty/light in the 2 mm deep U-shaped groove (Figure 4).

Discussion

Obtaining an accurate surface details of a preparation using impression materials is a known clinical challenge as the material is required to flow in a confined space. This problem is further amplified due to the hydrophobic nature of the impression material as it tend to repel in the presence of moisture on the prepared tooth and the surrounding gingiva (10). McCabe & Carrick (2006) reported that polyether produced more accurate impressions on moist gypsum dies with V-shaped grooves of varying depth, 0.5 to 1.8mm. While V-shaped groove may represent tooth preparation margin when knife-edged and bevelled margins are employed, U-shaped grooves are likely to be formed by chamfer and shoulder margins against the free gingiva (Figure 1). This study provides an insights towards the accuracy of monophase and dual phase impression materials against groove geometry and depth of grooves.

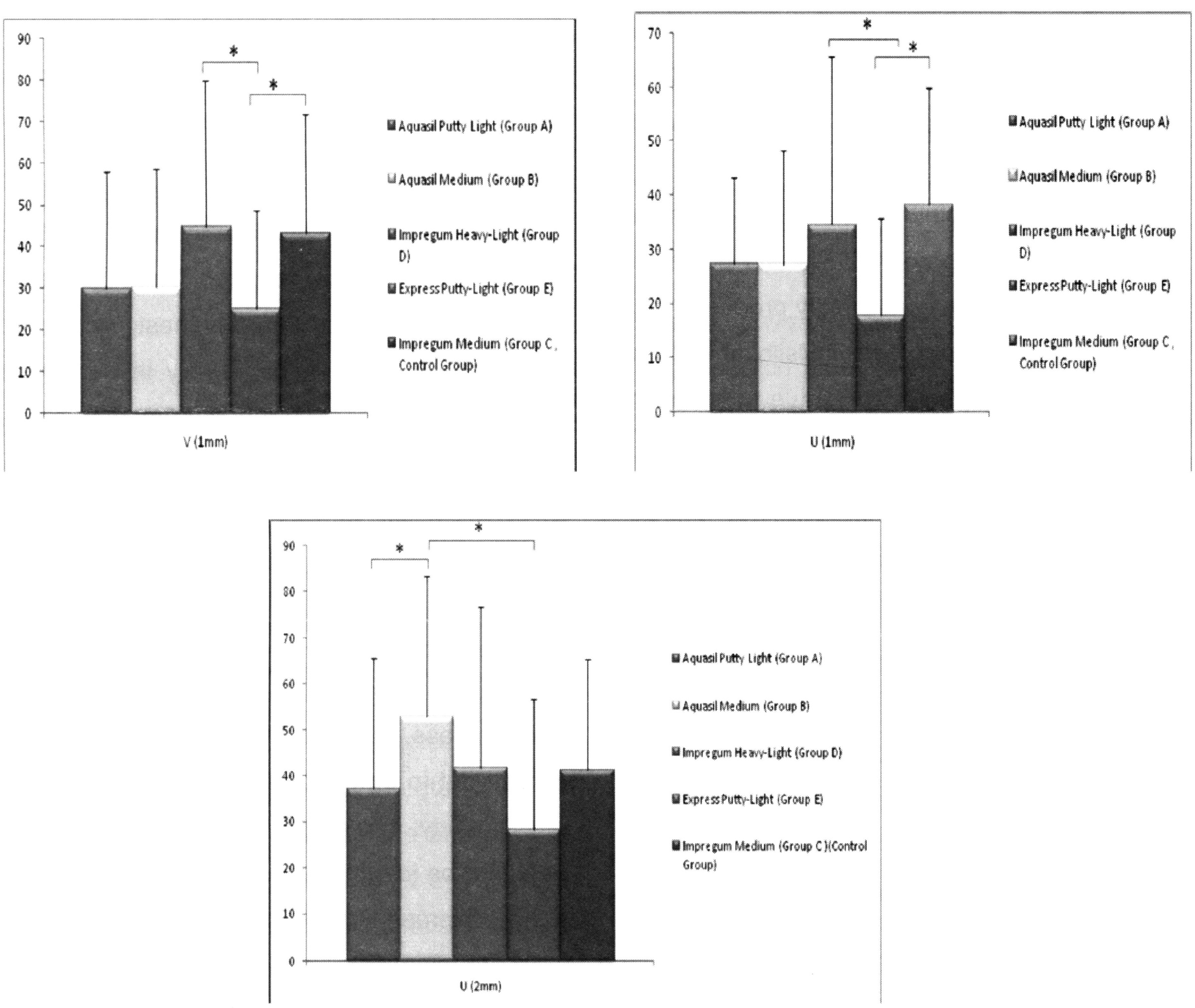

Figure 4: Significant difference in U- and V- shaped groove

In this study, the mean difference in depth was chosen to represent the ability of the test impression materials to wet and flow thus reproducing the surface detail of master dies. The smaller the mean difference in depth, the better the surface detail reproduction, suggesting that the material has good flow and wetting properties. Therefore, one may indirectly conclude that a material exhibit hydrophilic characteristics. It can also be anticipated that the consistency of the pastes might have an impact on the reproduction of the grooves. In general, the mean difference in depth produced by dual mix polyvinylsiloxane (Express™ XT Light Body / Express™ XT Putty Soft and Aquasil Ultra LV Smart Wetting® Regular Set / Aquasil Soft Putty-Regular Set) were lower compared to those obtained from single mix polyvinylsiloxane (Aquasil Ultra Monophase Smart Wetting® Regular Set). Meanwhile, the reverse was observed for polyether. The results of this study contradict those of other studies that have been reported in the literature (12,21) and polyether has been reported to consistently produced better results compared to polyvinylsiloxane in the reproduction of surface details due to its inherent hydrophilic nature (21).

In this study only single mix technique impression materials which is a medium-bodied was used. However, in the present study, both single and dual mix technique were used to simulate clinical application as the difference in the components of each impression materials may influence the outcome. Furthermore, different types of surfacant added to polyvinylsiloxane by different manufacturers also may affect the results. This was highlighted by Johnson et al (2003) who showed that mean roughness of impressions was influenced by the type of impression materials, its viscosity selection and the presence of moisture.

The results of this study showed that impression materials were not dependent on the type of grooves. It was expected that Impregum Medium would exhibited high accuracy due to its inherent hydrophilicity, however this was not observed. Polyether impression materials can swell when they come into contact with water unlike polyvinylsiloxane as shown by previous study Nissan et. al (2000) (22)

The most accurate surface detail reproduction was obtained from dual phase materials; Aquasil Putty-Light and Express-Putty-Light. The hydrophilic behaviour of these materials is attributed to the presence of surfactant (12). Among surfactants used in polyvinylsiloxane as non-ionic surfactant are nonylphenoxyl poly (ethyleneoxy) ethanol and ethoxylated long-chain alcohol (24).

Although the mean difference in depth between these materials was not significant, Express-Putty-Light exhibited the highest accuracy. Thus, further study is necessary to determine the effect of different type of surfactant in different type of impression materials.

The results of this study indicated incorporation of a non-ionic surfactant into polyvinylsiloxanes enhanced their hydrophilicity and led to the significant reduction in the contact angles (1,5,12).

Nevertheless, further investigation should be carried out to empirically verify the observation of this study. The exact type of surfactant also needs to be identified in each impression material as Express Putty-Light showed significantly lower mean difference in depth compared to Aquasil Putty-Light. Furthermore, the result of this study clearly showed that Express Putty-Light performed better than all impression materials tested. With regard of groove shaped, it was evident that Express Putty-Light recorded better surface detail reproduction with 1 mm depth than polyether irrespective of its shape and consistencies. This finding corresponded with the observation described earlier by Johnson et. al (8)

Nevertheless, contradictory results were observed for U- and V- shaped of 2 mm depth. Significant difference was only observed among PVS groups in the U- shaped groove of 2 mm. Aquasil and Express dual phase showed better surface reproduction compared to Aquasil monophase. Express Putty-Light impression material showed the most accurate surface detail reproduction in U-shaped groove of 2 mm depth.This is because in wide interface area, the hydrogen bond that existed within water molecules is far apart thus reproducing weak hydrogen bond and lowers its surface tension. This is further enhanced by the impression materials which have an affinity towards water. Hence impression material can flow easily into U-shaped groove compared to V-shaped groove of 2 mm. In V-shaped groove of 2 mm depth, no significant difference was detected for all impression materials. It was expected that dual phase PVS would showed significantly lower mean difference in depth but it was not so. In a narrow channel such as the V-shaped groove, the attraction of water molecule atoms to each other is stronger than the attraction between the water molecule surface and subsurface (23). As a result, the flow of any impression material on moist solid surface could be affected.

Conclusion

In conclusion, the measurement of mean difference in depth is purely material and groove dependent. Polyvinylsiloxane exhibited significantly better surface detail reproduction compared to polyether with Express Putty-Light exhibiting the least mean difference in depth. Dual phase polyvinylsiloxane performed better than monophase impression materials. Shapes of groove play an important role in determining of the flow and wettability of the impression materials.

Surface detail reproduction of V-shaped groove is not influenced by depth. U-shaped groove with 2 mm depth can be accurately reproduced by dual phase polyvinylsiloxane indicating impressions of U-shaped groove showed better surface detail reproduction than V-shaped groove.

Acknowledgments

This study was supported by University of Malaya research grant (# PS 311-2007B). My utmost gratitude to Associate Professor Kevin H.K. Yip, Adjunct Professor at School of Dentistry, Charles Sturt University, Sydney Australia, for his guidance and assistance in the preparation of this manuscript.

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